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The wind profile up to 600 meters at a flat coastal site; comparison between WRF modelling and Lidar measurements

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Abstracts

This study shows long-term ABL wind profile features by comparing long-range wind lidar measurements and the output from a mesoscale model. The study is based on one-year pulsed lidar (Wind Cube 70) measurements of wind speed and direction from 100 to 600 meters with vertical resolution of 50 meters and time resolution of 10 minutes at a coastal site on the West coast of Denmark and WRF ARW (NCAR) simulations for the same period. The model evaluation is performed based on wind speed as well as statistical parameters of the Weibull distribution of the wind speed time series as function of height. It is found that 1) WRF is generally under predicting both the profiles of the measured wind speed, direction and power density as well as 2) the scale (A) and shape (k) parameters of the Weibull distribution above 100 m. The latter signifies that the model suggests a wider distribution in the wind speed compared to measurements.

Methods

Site and measurements

The measurements were carried out at the Danish National Test Station of Wind Turbines at Høvsøre, which is located at the western coast of Jutland. Except for the presence of the North Sea to the west, the terrain is flat and homogeneous consisting of grass, various agricultural crops and a few shrubs. Wind speed is measured with cup anemometers at nominal heights of 10, 40, 60, 80, 100, 116.5 m. and the wind direction with wind vanes at 10, 60 and 100 m. To extend the height range in which data are available, observations from the 160 m top level at the nearest light tower are also used. In addition, for extended height measurements, a pulsed wind lidar (WLS70) has been operating near the meteorological mast between April 2010 and March 2011. The wind lidars Doppler shift based measurements for this study are processed into 10-min. average quantities of wind speed and direction The wind lidar measures from 100 m above the ground and every 50 m up till 1 to 2 km height dependent on the attainable 10-min averaged Carrier to Noise (CNR) ratio.

Numerical modelling

Wind profiles were predicted using the WRF ARW model version 3.2 (Skamarock et al. 2008). Data for initial and boundary conditions come from Final Analyses (FNL, Global Final Analysis Data) of the National Center for Environmental Prediction (NCEP, USA) global model. The physical options of model setup include the Noah land surface scheme, the Thompson microphysics scheme and the MYNN PBL scheme. The WRF model calculates the meteorological parameters at 41 vertical levels from the surface to pressure level 100 hPa. Eight of these levels are within the height range of 600 m that is analyzed in this study and the first model level is at 14 m. Model simulations were performed both in short term forecasts and long term analysis mode. The model is run in analysis mode. It uses the FNL global boundary conditions that are available every 6 hours on a 1 times 1 degree grid. Two domains with a horizontal grid size of 18 and 6 km respectively are used. The simulations are started every 10 days at 12:00 and after a spin up of 24 hours a time series of 10 minutes simulated meteorological forecast data from 25 to 264 hours is generated.

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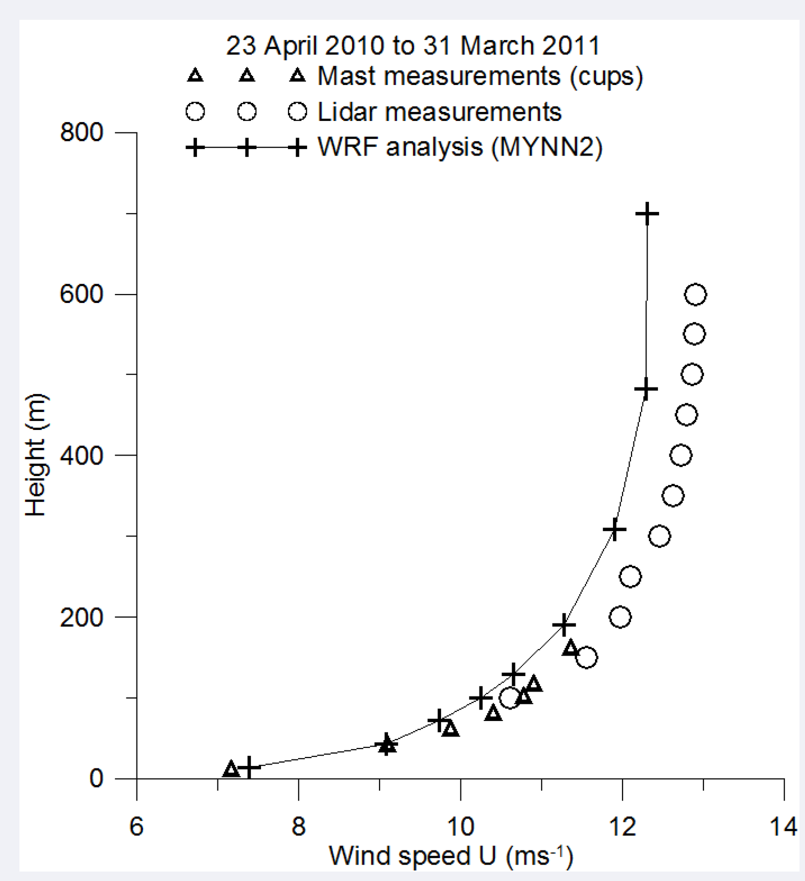
Results

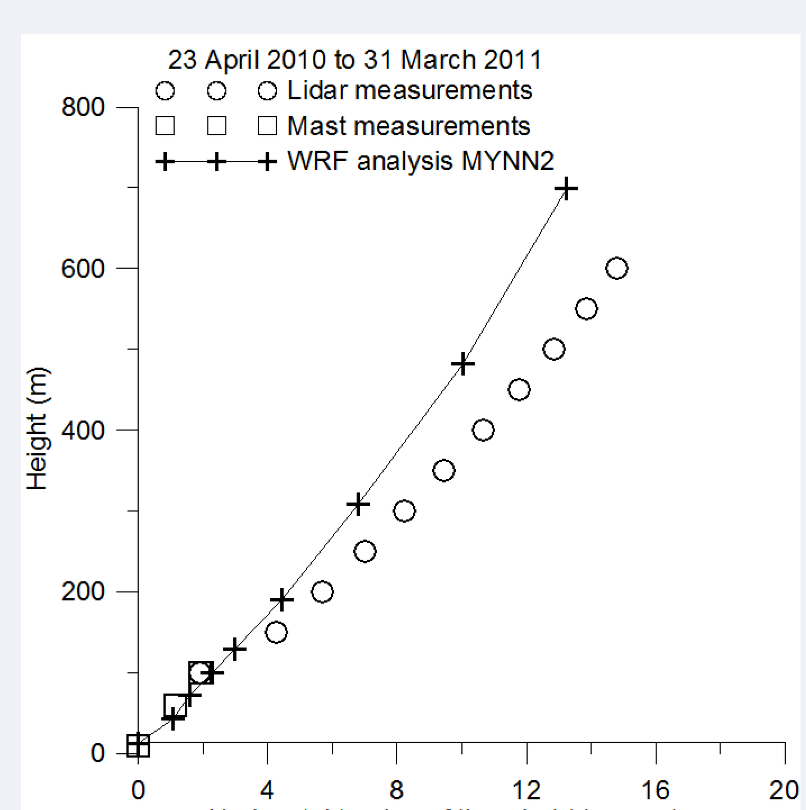
Figure 1 shows the profile of the mean wind speed for the period 23 April 2010 to 31 March 2011, based on simultaneous measurements at the meteorological mast and the wind lidar. Good agreement between the wind lidar measurements and the cup anemometer measurements at the overlap heights at 100 and 150/160 meters can be observed.
Near the ground agreement between the measurements and the WRF modeling analysis is good and above approximately 60 meters the model under-predict the mean wind speed.

Fig. 1



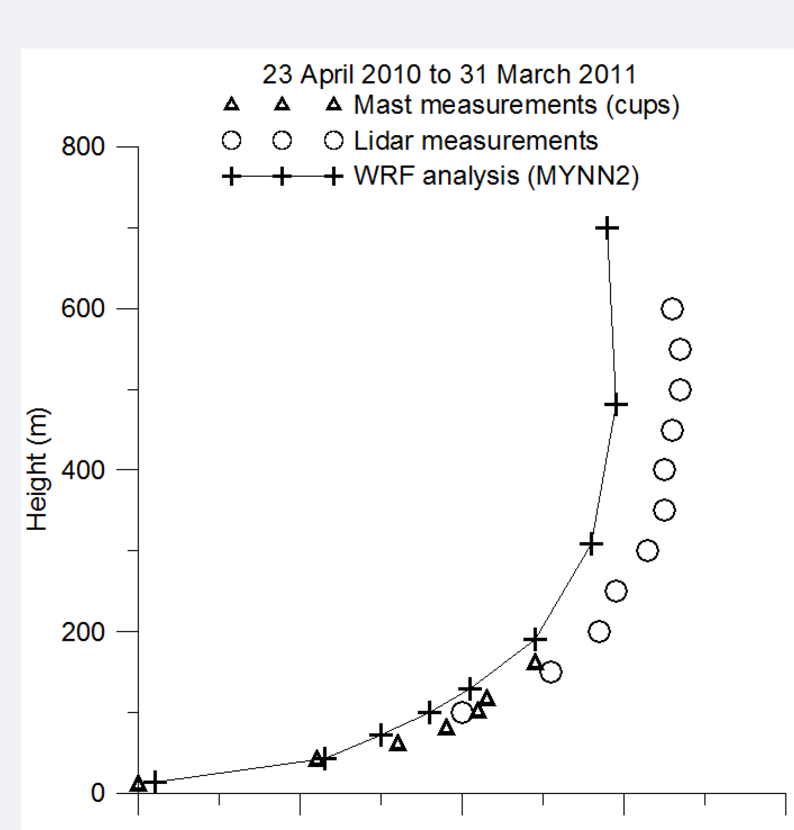
For the wind direction it can be seen in Fig. 2 that the WRF analysis produced a smaller wind directional turning than is actually observed.

Fig. 2



The shape parameter (A) parameter in the Weibull distribution is shown in Fig. 3. It can be seen that that the A parameter from the WRF simulations are smaller than observed.

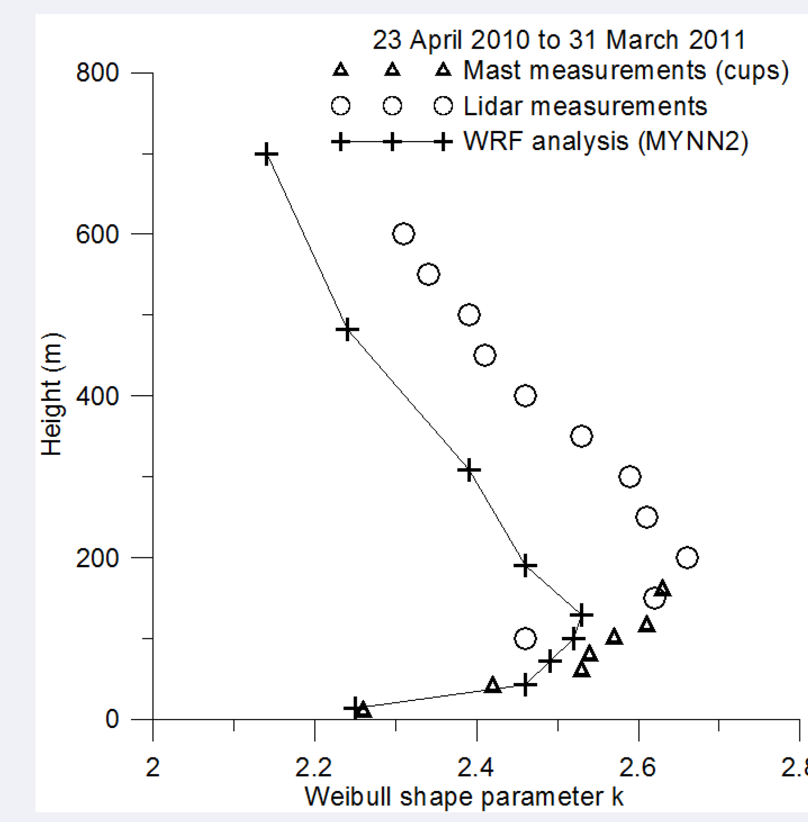
Fig. 3



Results

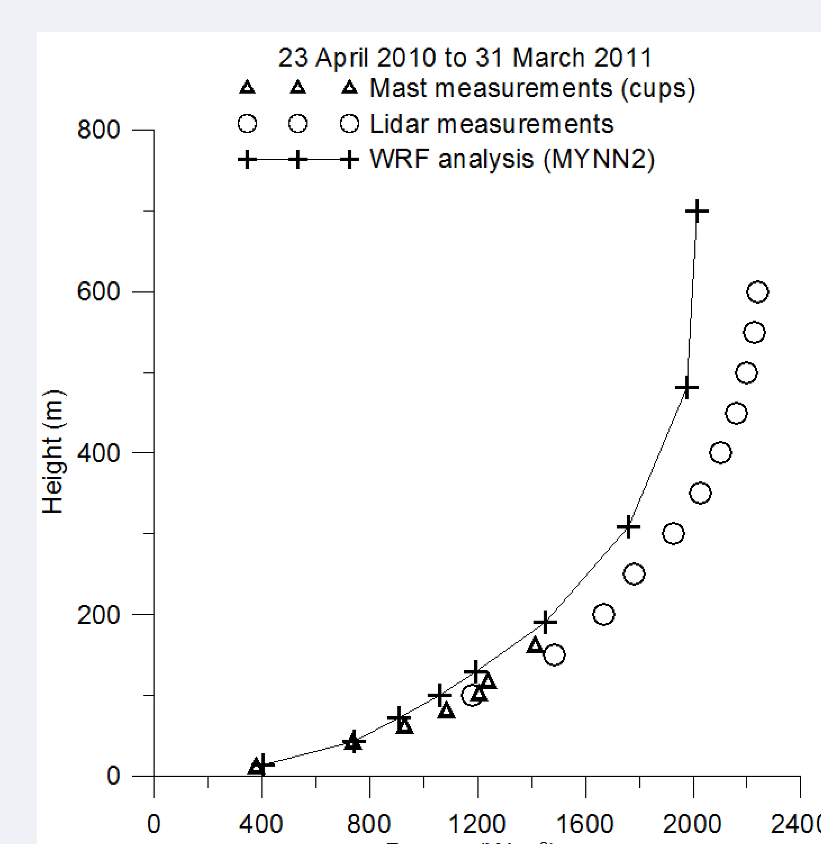
Also the shape parameter (k) parameter in the Weibull distribution that can be estimated from the WRF simulations is smaller than observed, Fig. 4. As expected (Wieringa 1989), the shape parameter has a maximum at about 100 to 200 meters height.

Fig. 4



Wind power density is an estimate of the effective power of the wind at a particular location.
From Fig. 5 it can be seen that near the ground there is good agreement between the power density estimated from the measurements and the model simulations. Beyond 60 meters it is found that the simulations underestimates the power density.

Fig. 5



Conclusions

In this study a full year of measurements of the wind profile performed at a coastal site has been analyzed and compared to a number of simulations carried out with the WRF model.
In general the WRF model under predicts the wind speed, scale and shape parameters in the Weibull distribution of the long term wind velocity, and the wind power density that can be assessed from the model simulations.

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Wieringa J. 1989. Shapes of annual frequency distributions of wind speed observed on high meteorological masts. Boundary-Layer Meteorology 47: 85-111.